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Impact in Practice

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IMPACT IN PRACTICE

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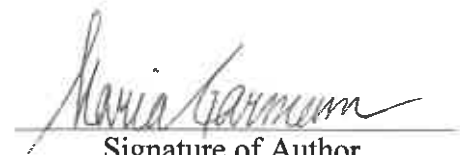
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Abstract

Medial Tibial Stress Syndrome (Shin splits) is an overuse injury caused by repetitive impact. If ignored it can lead to stress reactions and then stress fractures in the shins. This nagging injury is something that plagues many track athletes especially as they start to wear their competition shoes more frequently at practice to work on technical aspects of their events.

This paper investigates the relationship between ground reaction forces experienced by the athletes in each stride and what shoes they are wearing on their feet. Due to the fact that repetitive impact is a cause for shin splints, the conclusion of this project includes a new form of footwear that allows athletes to train for excellent performance with low impact. The objective of this project is to improve the athletic experience of track athletes.

The design process of this product titled ‘The Hybrid Shoe’ included many steps. First, there was a plentiful amount of research in order to understand the biomechanics of running. Many sketches and concept mock-ups lead to two ideas that were made into prototypes. The hybrid shoe idea prototype moved forward and was tested for its effectiveness by measuring the ground reaction forces of each stride and comparing it to other footwear worn in the sport of track and field.

Acknowledgements

First, I am grateful for my advisor Professor Peter Robbie for the opportunity to work on an independent project under his guidance and assistance. I am very thankful for Ryan Chapman's help in the biomechanical testing portion of this project and the insightful conversations we had that helped to point my project in the right direction.

I would like to thank my peers Regina Yan and Brian Francis for their helpful insights throughout this project.

I also thank my teammates on the Dartmouth Track and Field team for all their help filling out my initial survey, aiding in the testing of my product, and giving constant feedback about my idea. I would also like to thank Scott Roy and Meredith Cockrelle, both athletic trainers for the Dartmouth track team for their help explaining the common injuries experienced by track athletes.

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1 Introduction

1.1 Background

I am a '19 majoring in Engineering Modified with Studio Art with a minor in Human Centered Design. I am very interested in pursuing a career in product design and after a summer working for Converse, I am specifically interested in product design related to footwear. There are so many aspects of a shoe that can alter the user's comfort, performance, and experience in a shoe.

I am very passionate about sports, they have always been a part of my life and I am a heptathlete on the Women's Track and Field team here at Dartmouth. My objective for this project is to improve the athletic experience of a track athlete. As a member of a Division I track program, I have had the opportunity of experiencing first hand, the challenging student-athletes face as they strive for success in both athletics and academics.

When I decided to pursue ENGS 86 I knew I wanted to use the opportunity to investigate and learn more about the biomechanics of running. Around the time I was writing up my proposal for this project I noticed a sudden increase in complaints from my teammates about shin pain. At this time in our fall training we were transitioning from high volume conditioning that includes hill sprints and grass track interval workouts to more technical work that incorporates the use of competition footwear. I found it very interesting how the initiation of shin problems in my teammates seems to have been prompted or caused by the sudden change in footwear. My teammates inspired the idea for my project.

1.2 Track and Field

The sport of track and field at a glance seems simple, it tests the limits of athletic performance in running, jumping, and throwing. We can date this desire to compete back to

the times of the Roman Olympics; humans have always been challenging themselves to run faster, throw farther, and jump higher than their peers.

Today the sport of track and field consists of many events, these events are subdivided into five event groups; sprints, jumps, throws, middle distance, and distance. Sprints are a track running category that consists of distances ranging from 100m and 400m. These athletes optimize their fast twitch muscles to get up to speed as quickly as possible and maintain for the short length of a lap around the track or less. Distance is a track running category that includes the 3K, 5K, and 10K. In comparison to sprinters, distance runners optimize their slow twitch muscles and build up their endurance to hold a slower pace for a much longer period of time. Middle distance fits in between sprints and distance, this category consists of both the 800m and 1500m. These athletes must train both the fast and slow twitch muscles mentioned previously to optimize their ability to hold a fast pace over a relatively long distance. High jump, long jump, triple jump, and pole vault make up the jumps category in track, although all ranging in the specific motion incorporated in the event itself, there is a common thread across the event group to train explosive “hops” to maximize jumping performance. The throwing category consist of discus, javelin, shot put, and hammer throw. In these events typically higher body mass and explosive fast twitch muscles are advantageous in controlling the weight of the implement to get it to travel as far as possible.

All of these motions, running and jumping specifically involve tremendous amounts of impact on the body in both competition and in practice. To follow the expression “practice makes perfect”, good practice consists of repetition of desired motions. As an athlete pursues this sport, they become very event specific. By the time they get to the collegiate level of track they will be filtered into one of the event groups described earlier. With so much

repetition of motion in practice and very event specific practice, overuse and impact injuries are common. In order to maximize performance, track athletes look to get as much force out of the ground as possible, although very successful in accomplishing the task of maximizing performance, these high impact forces are the root cause of many injuries in the sport.

1.3 Footwear in Track and Field

In order to evaluate the ground reaction forces athletes are experiencing, we must first analyze what they are wearing on their feet. Each type of shoes transfers force differently depending on the layup of materials in the sole of the shoe. These materials have the ability to dampen ground reaction forces and protect the athlete from risk of overuse injuries such as shin splints. The following three descriptions of footwear are what is most commonly used in track practice. Depending on the event group, some footwear is used more than others, but to generalize all footwear is used at some point in the week by track athletes in practice.

1.3.1 Trainers

Any basic running shoe. Can range from minimalist to highly structured. Designed with cushioning, typically EVA (Ethylene Vinyl Acetate) or other closed cell foam materials with ideal compression set in the midsole to help with impact absorption to dampen the forces felt in each stride over many miles. A rubber outsole helps with the durability of the shoe to hold up over miles of running. This shoe is typically used for warming up, general training, and mileage.

1.3.2 Racing Flats

This shoe is a lightweight version of the trainer. Designed to mimic the weight and feel of the competition shoe without the steel spike traction element and with added

cushioning. Racing flats are used for interval and some speed workouts.

1.3.3 Competition Spikes

Competition spikes are designed to maximize force transfer between the athlete and the ground for excellent performance. For this reason, there is very little material between the athlete's foot and the ground. With each stride the athlete can maximize the force they get out of the ground by minimizing the forces lost through cushioning dampening. The forefoot of competition spikes have a plastic rigid plate that holds steel spikes in place for traction. These shoes are made for competition but often times used during practice. To a degree, the use in practice is validated because the athlete must feel comfortable in the footwear before competition, but too much practice in competition footwear causes the athlete to experience a lot of unnecessarily high vertical forces.

2 Research

2.1 Injuries in Track and field

Due to the nature of the performance driven sport, athletes are asked to put high strain on their bodies to maximize performance¹. Repeated high strain can lead to fatigued muscles if not strong enough. Through research and conversations with athletes and athletic trainers I investigated what injuries are most common and what are their root causes.

2.1.1 Achilles Tendonitis

The Achilles tendon does a lot of work to dampen the impact in each running stride. It elastically absorbs the initial impact when the front foot strikes. After stretching,

¹ Larsson, J. & Rasmussen, A. (2018) Long distance track spike design: Maximizing running performance (Master's thesis) Retrieved from Chalmers University of Technology.

it contracts again, releasing the energy into the next stride.² The frequent and violent lengthening of this tendon can very quickly lead to Achilles tendonitis if not treated correctly. In relation to footwear, Achilles problems can arise when wearing sprinting spikes because this form of competition footwear moves the athlete to run exclusively on their toes, making the Achilles tendon work harder than normal.

2.1.2 Medial Tibial Stress Syndrome (Shin Splints)

Shin Splints are the most common overuse injury among track athletes being responsible for 6-16% of injuries among runners³. In conversation with athletic trainer Scott Roy at Dartmouth College I learned a lot about the root causes of shin splints, this injury is one that seems to have many causes but the two main issues are muscular imbalance and overuse.

This muscular imbalance is typically related to attenuation of pronation (how quickly one pronates and by how much). Pronation is forefoot abduction or eversion, this motion puts stress on the medial structures, stretches out the posterior tibialis and consequently pulls on the bone connection which in turn causes the inflammation and shin associated with shin splints. This pronation issue is typically solved by adding inserts in the shoes of athletes to limit their pronation in each stride. There are also many exercises performed to help strengthen the calf muscles in attempts to fix the muscular imbalance.

The second cause of shin splints is from repeated use. Constant repeated loading to the medial structures causes something called hypertrophy. Hypertrophy is the process

² Larsson, J. & Rasmussen, A. (2018) Long distance track spike design: Maximizing running performance (Master's thesis) Retrieved from Chalmers University of Technology.

³ Thacker, Stephen B., et al. "The Prevention of Shin Splints in Sports: a Systematic Review of Literature." *Medicine & Science in Sports & Exercise*, vol. 34, no. 1, 2002, pp. 32–40., doi:10.1097/00005768-200201000-00006.

in which the muscle gets bigger, increases in cross sectional area from overuse. This process causes inflammation in the shin bone connection due to the change in size of the muscles surrounding the bone.

Old shoes and hard surfaces are typically associated with shin splint injuries. This is due to the fact that old shoes lack cushioning aspects to dampen vertical loads. With this decrease in cushioning, they also lack support to help avoid pronation problems. In regards to hard surfaces, similar to the shoe cushioning, surfaces with limited compression set or rebound make it so that the athlete is absorbing the forces. When possible, training on soft surfaces or cross training on a bike is a great way to avoid straining impact forces.

2.1.3 Patella Tendonitis and Heel Bruising

Both patella tendonitis and heel bruising tend to be injuries most frequently experienced by jumpers. The repetitive loading of the jumping leg can cause a lot of strain on the patella tendon. Heel bruising is more triple jump specific and is caused by the second phase of their jump where they slam on their heel in transition to the third and final phase of the jump.

2.2 Understanding Biomechanics

In order to understand the data that I collect later on in my project to prove the effectiveness of my product, I needed to understand the biomechanics of running. With each stride a force transfer occurs between the ground and the athlete's foot. To visually understand this concept; the two diagrams below depict two kinds of running by way of a force over time graph with data taken an athlete running over a force plate. Figure 1 depicts a heel strike stride, the key feature to note here is the little spike to the left of the

curve that is the heel slamming into the ground.⁴ The peak maximum force experienced in each stride matters, but it also matters how quickly you get there. For this reason, a sharp spike in data like when the heel hits the ground before the rest of the foot is presumably bad.

Figure 2 shows a force over time diagram for a forefoot landing stride. Track runners typically strive for this type of stride because it is both natural and powerful. It closely resembles what a barefoot running stride looks like, using the body's evolutionarily derived mechanisms for fast propulsion.⁵

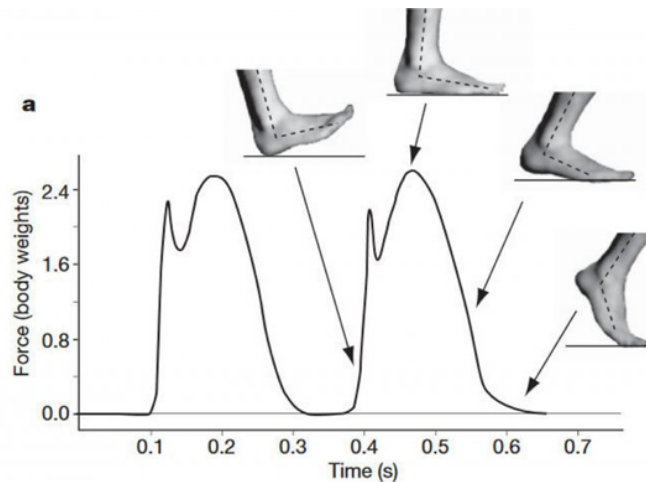


Figure 1: GRF diagram for Heel Strike stride⁶

⁴ Hutchinson, Alex. "It's Time to Rethink Barefoot Running." *Outside Online*, Outside Magazine, 26 Feb. 2019, www.outsideonline.com/2390686/barefoot-running-biomechanics-study?utm_medium=social&utm_source=email&utm_campaign=onsiteshare.

⁵ Larsson, J. & Rasmussen, A. (2018) Long distance track spike design: Maximizing running performance (Master's thesis) Retrieved from Chalmers University of Technology.

⁶ Hutchinson, Alex. "It's Time to Rethink Barefoot Running." *Outside Online*, Outside Magazine, 26 Feb. 2019, www.outsideonline.com/2390686/barefoot-running-biomechanics-study?utm_medium=social&utm_source=email&utm_campaign=onsiteshare.

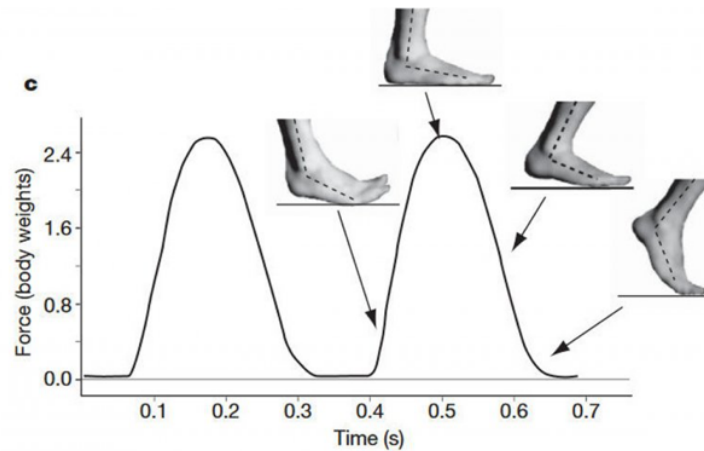


Figure 2: GRF diagram for Forefoot Strike stride⁷

2.3 Connecting Injuries to Science

As you can see from the ground reaction force (GRF) diagrams in the above section, there is a lot of scientific research behind how humans run. Furthermore, there is a lot of research connecting the forces experienced per stride to common overuse injuries. For example, in a master's thesis explaining the construction of a new long distance competition spike it is stated that there is "a correlation between high vertical impact forces and tibia shock and stress fractures."⁸ To remedy these impact forces, it is suggested that reducing dynamic load and shocks is important, rest being the proven remedy, but the properties of the shoes, such as cushioning, may help reduce the shock when hitting the ground."⁹

In conversation with Scott Roy, an athletic trainer for Dartmouth College, he calls track spikes "a necessary evil...they give you the performance benefit, but with less cushioning all

⁷ Hutchinson, Alex. "It's Time to Rethink Barefoot Running." *Outside Online*, Outside Magazine, 26 Feb. 2019, www.outsideonline.com/2390686/barefoot-running-biomechanics-study?utm_medium=social&utm_source=email&utm_campaign=onsiteshare.

⁸ Larsson, J. & Rasmussen, A. (2018) Long distance track spike design: Maximizing running performance (Master's thesis) Retrieved from Chalmers University of Technology.

⁹ Larsson, J. & Rasmussen, A. (2018) Long distance track spike design: Maximizing running performance (Master's thesis) Retrieved from Chalmers University of Technology.

that force is translated through your tissues rather than attenuated by the materials in the footwear”. To reiterate this point, although the performance benefits are optimal for competition, the high strain on the body by wearing these shoes can be detrimental to the tissues of the lower leg if these shoes are used too frequently.

2.4 Collegiate Track Athlete Survey

In hopes to understand the user better and make sure my product would cater to their needs I conducted a survey of Collegiate Track Athletes. I got 92 responses from athletes representing all event groups and having had experience in the sport ranging from 3 to 15 years. Of these respondents, 69% have had experience with shin splints in the past. When asked if they wear competition footwear in practice, 67% of the respondents said yes. To better understand the prevalence of competition footwear in practice I asked why. The responses included “practice how you compete”, “for traction around tight indoor 200m track turns”, “speed workouts”, and “technical work”.

3 Initial Testing

3.1 Previous Study

During the research process, I came across an article in the Journal of Sports Science and Medicine that published the testing results for the study I had planned to perform. This study measured the ground reactions forces (GRF) of runners in three different types of shoes; trainers, racing flats, and competition spikes. This study came to the conclusion that “The GRF experienced during running is significantly increased in competitive footwear compared to regular running shoes.”¹⁰

¹⁰ Logan, Suzanna, et al. “Ground Reaction Force Differences Between Running Shoes, Racing Flats, and Distance Spikes in Runners.” *Sports Science and Medicine*, 9 Mar. 2010.

3.2 Testing Results

With interest in validating this research I went about trying to recreate this study. Using instrumented insoles made by ‘loadsol’ that fit in the athlete’s shoe under the foot and connected to an app on my phone via Bluetooth, I was able to track the ground reaction forces across time. I asked 10 of my teammates to run 20 meters wearing the instrumented insoles in pair of their trainers and then again in a pair of their competition spikes. I asked each runner to try and run at the same speed in both the trainers and the spikes in order to allow for a better comparison between the forces in the two shoes. I tracked the speed of each test with Brower Timing system gates in order to validate this consistency.

3.3 Analyzing Results

For each participant in the testing I had four sets of data. The ground reaction forces over time in trainers left foot, trainers right foot, spikes left foot, and trainers right foot. To visually analyze this data I graphed these results via Matlab and compared the maximum GRF between each participant. Due to difference in body weight and slight differences in speed between individuals I did not compare across the entire group, but rather between the two sets of data for each individual. The following graph shows an example of the results from testing which validated the study found in the Sports Science and Medicine¹¹, the ground reaction forces experienced when wearing track spikes is consistently higher than that of trainers.

¹¹ Logan, Suzanna, et al. “Ground Reaction Force Differences Between Running Shoes, Racing Flats, and Distance Spikes in Runners.” *Sports Science and Medicine* , 9 Mar. 2010.

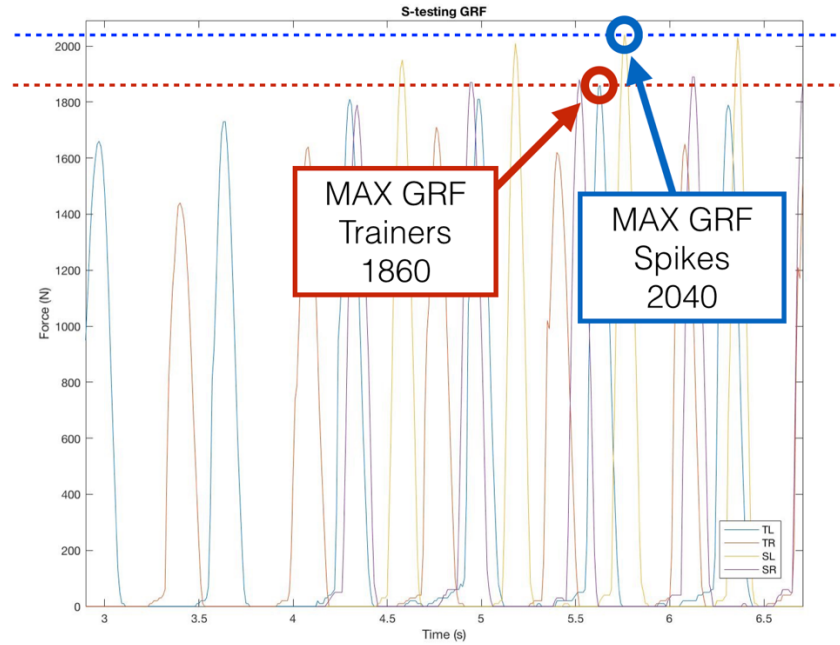


Figure 3: GRF between Trainers and Spikes

4 Defining the User

The target user is track athletes, ranging all ages and levels of performance. This project will target athletes in track events that involve running (incorporating almost all events but excluding most throwing events). Furthermore, there will be an emphasis on sprinters and jumpers as they are event groups that often train in competition footwear due to speed interval workouts and technical training. This user can be someone who has past or current experience with impact related injuries, including but not limited to shin splints.

Additionally, this can be an athlete that wishes to avoid impact related injuries. In order to design for this user, it is important to understand what is most important to them. Track is a very specialized sport and athletes desire the ability to practice how they compete to best prepare to compete at the highest level come race day.

5 Design Process

5.1 Need definition

There is an evident need to reduce the impact experienced during training in the sport of track and field in order to maximize performance by minimizing the prevalence of impact related injuries. How might we develop better shoes to allow athletes to train for performance with low impact?

5.2 Specifications

Number	Specifications	Justification	Quantification	Testing
1	Durable	Not helpful if easily broken	Last an entire season	Evaluate works-like model after testing
2	Easy on/off	Ease of use for athlete	Less than 1 minute	Time subjects using the product
3	Effectiveness	Needs to successfully reduce impact	GRF proto < GRF spike	Testing with instrumented insoles
4	Comfortable	discomfort fosters bad performance	7/10 or better rating from testing	Subjects try on product and rate for comfort
5	Doesn't effect stride	Importance to practice how you compete	Stride length same as trainer and spikes	Compare stride length (seconds)
6	Safe	Not something that will create more injury	No injury in testing	Hard to test due to safety
7	Feasibility	Can compete project in 10 weeks	5 weeks to build	Evaluation of prototype
8	Weight	Lightweight shoes are desired for optimal performance	less than 0.5 kg	measure the weight in kg

Table 1: Specifications

5.3 State of the Art

To begin the design process, I started by analyzing the current state of the art processes for reducing impact in practice. Inspiration came from the Mobile Virtual Player (MVP), a robot football dummy that allows players to practice tackling without causing harm to their teammates by way of tackling incorrectly. I really liked the philosophy of this product in using technology to give athletes the feel of the game without the heavy impact involved in the game.

5.4 Initial Sketches

Most of my initial sketches revolved around finding a way to add some element of cushioning to pre-existing footwear used in practice.

5.5 Alternatives

After sketching out many ideas, I came up with four ideas/alternatives to test out in mockups. These ideas included Spike Bumpers, Cramp-on Cushioning, Cramp-on Spikes, and a Hybrid Shoe.

5.5.1 Spike Bumpers

This idea would incorporate an added element to competition spikes. These donut-shaped bumpers would be connected by way of the typical spike screw-in connection. A pro for this idea is that it is very versatile, it could fit any competition footwear from sprint spikes to high jump and pole vault. The negative to this idea would be its lengthy on and off process. Track athletes typically change the steel spikes in their shoes two to three times a season, this new idea would ask them to change spikes before and after every competition, a process that can be somewhat tedious.

5.5.2 Cramp-on Cushioning

This idea incorporates an added element to competition spikes. A second identical spike plate would be connected by longer spikes with a layer of cushioning in the middle. A pro to this idea is that it would fit each competition spike perfectly because it would have a identical second spike plate, the shape of the bottom of the shoe should not be effected. It can be assumed that therefore this would not effect the athlete's stride. Some of the negative aspects of this idea are that it must be specific to each pair of spikes, not making it very cost effective. In my mockup process I ran into issue with the connection between the spike plates and the durability of such a connection.

5.5.3 Cramp-on Spikes

Adding a traction element to racing flats takes the cushioning aspects of the flats and incorporates the desired traction aspects of the competition spike. Similar to the previous idea, I envision there being an issue with the connection between the spike plate and the flat. This idea would also have to be relatively specific to different types of shoes.

5.5.4 Hybrid Shoe

This idea is different than the rest in that it does not involve a mobile aspect. Rather than creating pieces that can be taken on and off, the hybrid shoes is simply a new shoe for training that combines the benefits of the racing flats and that of competitive footwear. Hybrid training shoe. This hybrid shoe is a racing flat with a spike plate connected to the forefoot.

5.5.5 Alternatives Matrix

In order to decide with which idea to move forward, I created an alternatives matrix that compared each idea to my list of specifications as well as weight for each

specification. As you can see in the following alternatives matrix, the Hybrid Shoe and Spike Bumper ideas were the highest scoring when compared to the defined specifications for this project.

		Durable	Easy on/off	Effective	Comfort	Consistent Stride	Safe	Feasibility	Weight	Total
	Scaling	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	
	Weighting (1-5)	3	4	5	5	4	4	2	3	
1	Spike Bumpers	3	1	4	5	5	4	3	5	115
2	Cramp on cushioning	1	2	4	1	1	1	2	3	57
3	Cramp on spikes	2	3	4	3	3	1	2	2	79
4	Flats/spikes hybrid	5	5	5	5	5	5	5	4	147

Table 2: Alternatives Matrix

5.6 First Prototypes

Moving forward with the two ideas I started by creating the first prototypes of the Spike Bumpers and Hybrid shoe.

5.6.1 Spike Bumpers

The first prototype of this concept was mounted on a Nike Sprinting spike. The bumpers were created from Sorbothane ‘comfort and performance’ insoles. This high density gel has great shock absorption properties. The donut shape of the bumper is glued to a metal washer which is connected to the shoe by way of the ¾ inch steel spike screwed threw the washer and into the spike receptacle. into the shoe to hold to the bumper in place. Below shows the works like model and CAD drawing of the looks like model for this idea.



Figure 4: Bumper Prototype

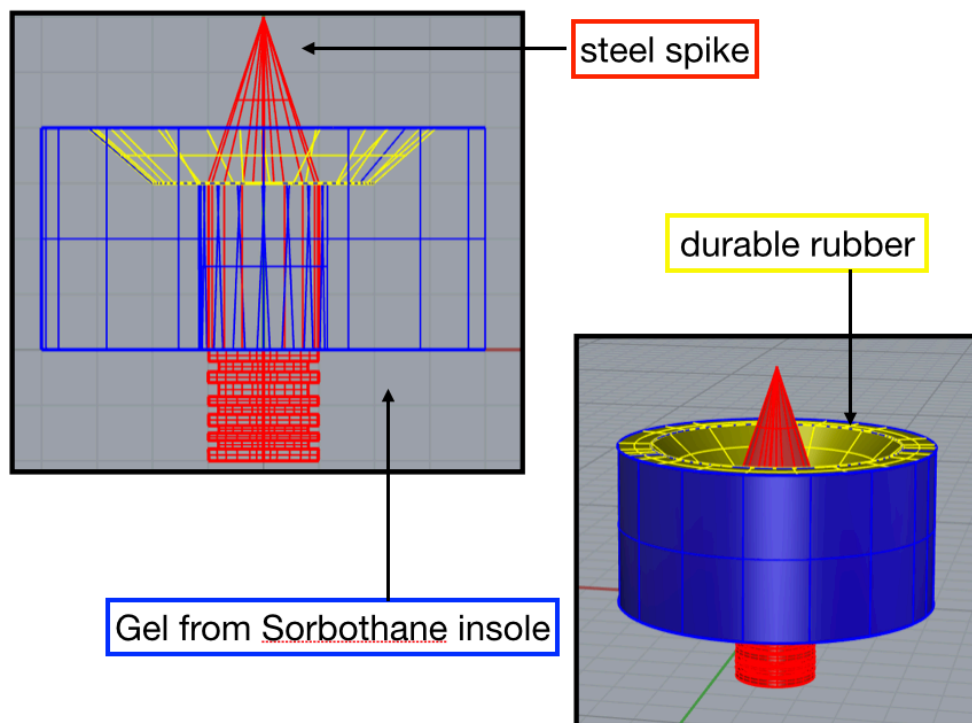


Figure 5: Bumper Rhino 3D model

I shared this idea with a few experts in the footwear industry. One contact named Matthew Hennessy who works at Ortholite explained to me how “Force transfer in spikes moves through the metal to the back of the spike receptacle inside the shoe”. For this reason, cushioning on the outside of the shoe will not be much help to dampening this

force transfer. I saw this insight as a dead end for my spike bumper idea and it helped me to focus in on just one idea.

5.6.2 Hybrid shoe

The first prototype of my hybrid shoe idea consists of a New Balance racing flat and an Adidas long jump spike plate. Manufactured in the machine shop, I ripped apart the long jump spike to expose the plastic spike plate. Then I sanded away the tread pattern on the racing flat until the spike plate lined up perfectly with the top of the rubber outsole. The spike plate was then glued to the forefoot of the racing flat using *Barge All Purpose Cement*. Originally I had planned to use epoxy for this connection, but epoxy would not allow the flexibility I needed to allow proper mobility in the forefoot of the shoe. Figure 6 shows the final result of the manufacturing process of the hybrid shoe prototype. Feedback from teammates that tried on and ran in the shoe helped me to realize that although this long jump spike fits the top of the shoe, the aggressive nature of the long jump spike plate makes for an uncomfortable shoe. It was rated 2 in a 1-5 comfort rating.



Figure 6: Hybrid shoe Prototype

6 Final Design



Figure 7: Hybrid shoe Final Design

6.1 Anatomy of Design

The same process was followed in the manufacturing of the final hybrid shoe design. The design is made from the Nike Zoom Streak 6 racing flat and the Nike Zoom Matumbo 6 distance competition spike. The plastic spike plate of this distance competition spike is much less aggressive compared to the previous prototype. This spike plate is more flexible due to the fact that it is made out of a thinner plastic material. As a result, the final design has less added weight from the spike plate addition. Furthermore, the steel spikes from the Nike Matumbo 6 are fixed, meaning they can not be interchanged like most spikes. For this reason, there is no threading into the spike plate, another reason for the lightweight aspect of this spike plate. This also does a great job of depicting what I would imagine a manufactured version of this shoe to look like because there would be no need to change out spikes and

fixed spikes would help to limit the weight of the steel spikes.

6.2 Testing

In order to test for how the final design measured up to some of the specifications I conducted another round of testing. The limiting factor for number of participants in this testing was the size of the Hybrid Shoe I wanted to test. This shoe is a size 9 men's/10.5 women's. Being a larger than average shoe size for women and smaller than average for men, I was only able to find four teammates with corresponding shoe sizes that were willing to aid in my testing process. The testing group consisted of two women and two men.

Using the same instrumented insoles from earlier, I was able to track the ground reaction forces across time as my 4 teammates as they ran 20 meters in trainers, spikes, and the Hybrid Shoe. I asked each runner to try and run at the same speed in all shoes in order to allow for a better comparison between the forces in the two shoes. I tracked the speed of each test with Brower Timing system gates in order to validate this consistency.

6.3 Specifications

The final design of the hybrid shoe idea meets all of the defined specifications.

Number	Specifications	Quantification	Testing	Results
1	Durable	Last an entire season	Evaluate model after testing	Stayed in tack for testing
2	Easy on/off	Less than 1 minute	lacing time = lacing time for normal sneakers	normal lacing time
3	Effectiveness	GRF proto < GRF spike	Testing with instrumented insoles	GRF proto < GRF spike
4	Comfortable	7/10 or better comfort rating from testing	Subjects try on product and rate for comfort	100% testers rated 5/5 in comfort
5	Doesn't effect stride	Stride length same as trainer and spikes	Compare stride length (seconds)	no change in stride length
6	Safe	No injury in testing	Hard to test due to safety	no injury in testing
7	Feasibility	5 weeks to build	Evaluation of prototype	built in 5 weeks!
8	Weight	less than 0.5 kg	measure the weight in kg	0.409 kg

Table 3: Specifications and Results

6.3.1 Durable

This spec was hard to test due to the fact that the ideal quantification is for the shoe to hold up for an entire 6-month long season. The fact that the shoe held up during testing is enough to extrapolate that it will also hold up over the course of a season.

6.3.2 Easy on/off

Due to the fact that these hybrid shoes are made from preexisting racing flats, there was no new technology that would add time to the lacing process.

6.3.3 Comfortable

When asked to rate the shoes on a scale from 1 to 5 (5 being extremely comfortable), every participant in the survey rated the shoes to be 5 out of 5 comfort. This was very exciting because the first prototype had issue with comfort due to the rigidity of the spike plate.

6.3.4 Safe

With a strong bond between the spike plate and racing flat, this new shoe passes the safety spec with flying colors.

6.3.5 Feasibility

The fact that this product was manufactured within the ten week term proves its feasibility.

6.3.6 Weight

This specification looked to keep the weight of the product the same or lighter than a pair of trainers. More specifically, to be under 0.5 kg would be an optimal weight.

6.3.7 Doesn't effect stride

The data collected from testing was used to check the effect of the runner's stride when wearing the hybrid shoes. The instrumented insoles reported numbers for force over time. To find the time of stride length I used Matlab to find when the force is equal to zero. This zero force represents the foot's time spent in the air. By measuring the time between the start of two consecutive zero force sections I successfully found the stride

length. I averaged the stride length for each individual between their right and left foot for each type of shoe from testing. There was no significant difference in stride length between any of the shoes. This helps to prove that the hybrid shoe meets this specification because it did not affect the stride of the athlete.

6.3.8 Effectiveness

The data collected from testing also helped to prove the hybrid shoe's effectiveness. In order to better visualize the data, I graphed each participant's force diagrams and calculated the maximum force experienced in each type of shoe. As you can see in the table in Appendix I, as hypothesized and proven in the initial testing, participants experienced the highest ground reaction forces when wearing competition spikes. The hybrid shoe prototype and trainers had about the same numbers for ground reaction forces which is exactly what the effectiveness specification asked for.

7 Conclusion

In conclusion, this project was a success. In order to prepare myself to analyze the data for testing I had to research and learn a lot about the biomechanics of running. From my experience in the sport of track and field I had so much passion for this project and hoping to solve the issues in training that are leading to impact related injuries. Through testing the final product proved to be effective in dampening the impact forces similar to that of a trainer. Due to the fact that many impact injuries are related to overuse injuries, there is no immediate way of knowing if this product will solve the issue. Next steps for this project would be to incorporate the Hybrid Shoe into a training program so that it can be tested over time to investigate if it, in fact, has the power to reduce the prevalence of shin splints in track athletes.

APPENDIX

Appendix A

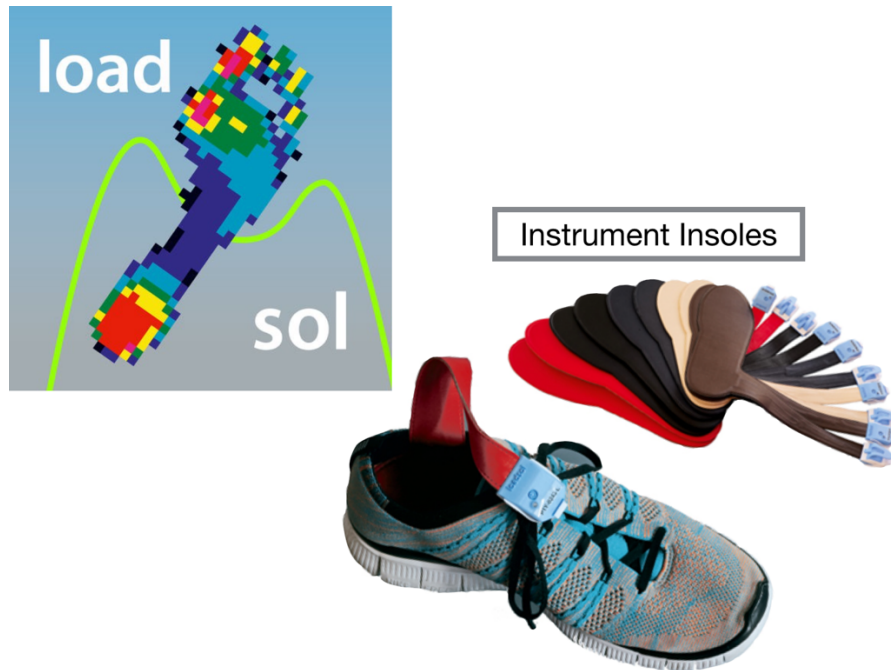


Figure A1: equipment used for testing

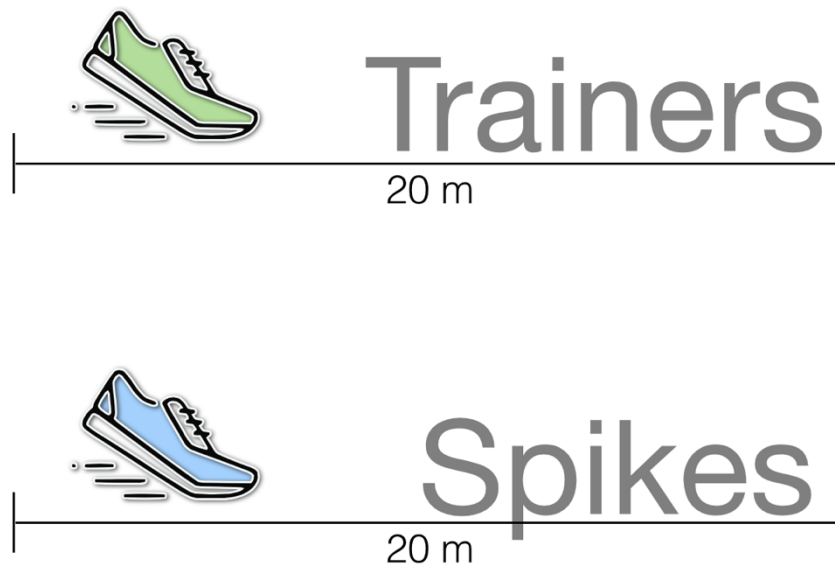


Figure A2: Testinf set up schematic

Name	Weight	20m trainer	20m flats	20m spikes
Maria	145	3.12		4.999
		3.34		
Tim	195	2.45		2.58
kayla	140	3.11	3.57	3.23
			3.72	
jackie	145		2.97	3.19
			3	3.19
nicole	120		4.04	
			3.11	
PJ	175		3.7	
			3.83	
will	147		3.45	3.43
anoush	130	3.91		3.33
sade	123	3.49		3.19

Table A1: Timing from testing

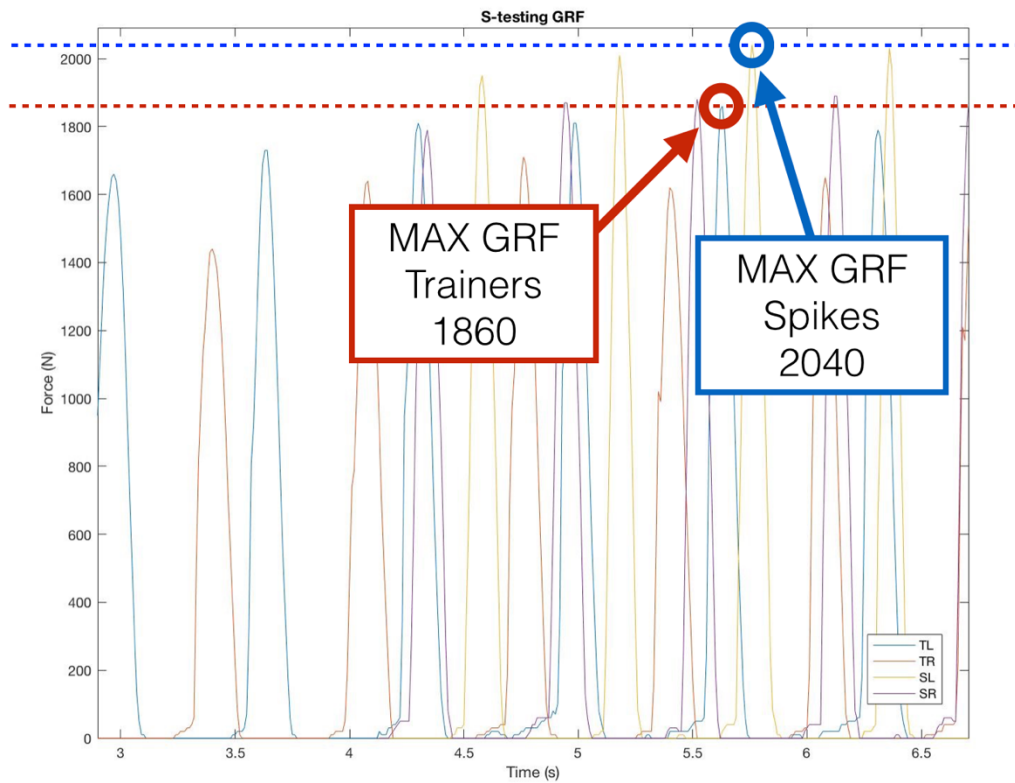


Figure A3: GRF graph with max forces

Appendix B

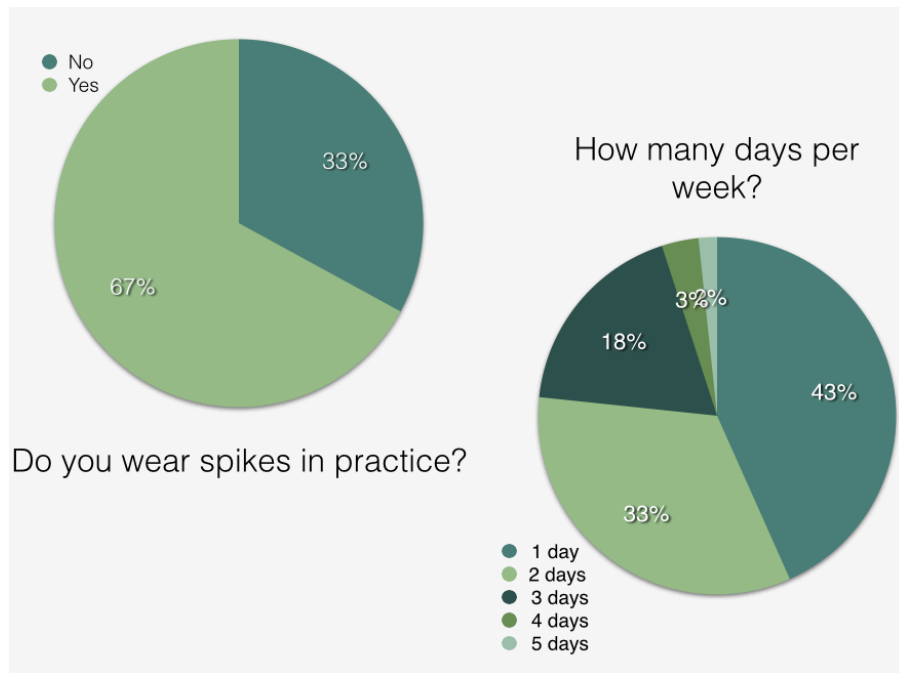


Figure B1: Results from survey

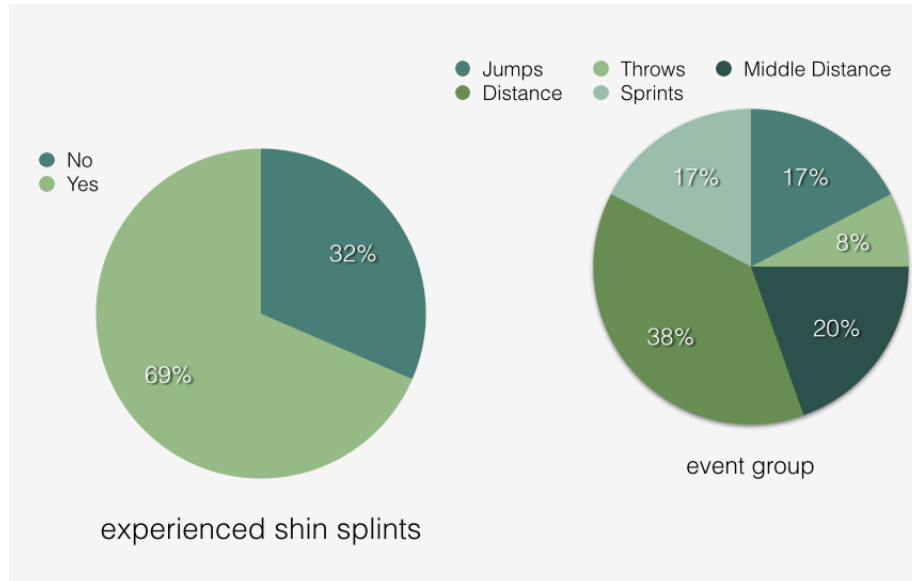


Figure B2: Results from survey

“Practice how you compete”

“traction”

“Jumps and hurdles”

“speed workouts”

“starting blocks practice”

Why do you wear spikes at practice?

“lightweight”

“Strides”

“to practice hurdles”

“need traction for tight turns in indoor track for
speed workouts”

Figure B3: Responses from survey

Appendix C

Conversation with Scott

Shin splints related to orthotics?
 ↓
 muscular imbalance
 ↓
 weakness bc of attenuation of pronation
 ↓
 pronation → how quickly pronates
 ↓
 turns in/out → how much

pronation = forefoot abduction, eversion.
 puts stress on medial structures
 ↓
 posterior tibial is stretched out
 ↓
 pulls on bone connection

pronation → stress on medial tendons, pulls on connection to bone
 ↓
 shin pain (fascial connection)
 OR
 repeated use
 ↓
 hypertrophy → muscle gets bigger
 ↓
 increase cross section area

lower leg compartment → muscle flexes toes, flexes big toe, inversion/prevent pronation
 ↓
 inflamed by overuse, bigger from lots of training

MTSS, medial tibial stress syndrome
 ↓
 pronation problem
 ↓
 looser motion in foot (flat foot)
 high arch → more rigid
 faster you run, longer the stride
 longer the stride, more dorsiflexion, which stretches toe muscles
 more impact, higher ground reaction time
 spread that impact on force translation over longer period of time

initial contact to ground to greatest force experienced, time?
 Peak force matters
 ↓
 ALSO, how quickly you get there
 performance deficit from force dampening response to ideas

durability, adding weight
 YES → adding cushioning helps
 ↓
 limit pronation or cushioning

heel strike, mid foot strike
 ↓
 toe runners → distance runners
 ↓
 sprints
 heel lift insert reduces the amount of dorsiflex + therefore amount of stretch on the muscle
 Medial heel lift ← custom orthotics
 ↓
 limit pronation keeps from getting into pronator
 ↓
 less effective for distance sprinters

high arch people, low % w/ medial tibial syndrome (MTSS)
 shift arch, effected by sudden force
 ↓
 more prone to stress fractures
 exercise induced anterior compartment syndrome
 old shoes
 lack of cushioning + stability
 Spine are a necessary evil
 ↓
 unstable + so little cushioning
 ↓
 Force translated through tissue rather than attenuated by footwear

Figure C1: Conversation notes with athletic trainer Scott Roy

Conversation w/ Meredith

Shin pain comes later in the season
 ↓
 major shift when technical training picks up
 ↓
 achilles + calf problems from spikes
 ↓
 spikes get you on your toes
 ↓
 sprint on balls of your feet
 ↓
 spikes keep you on the balls of your feet

Shin pain → surfaces
 ↓
 major differences when surfaces readjust
 ↓
 practice how you compete to some extent
 ↓
 surface is bigger thing
 ↓
 strengthening the foot
 ↓
 ankle + big toe flexibility
 ↓
 spine
 ↓
 low profile
 ↓
 sneakers
 ↓
 big heel drop → not great getting on toes

low profile shoe → minimal heel drop
 ↓
 running in spikes
 ↓
 big toe takes a lot of force
 ↓
 if not strong, collapse
 ↓
 posterior tib over involvement
 ↓
 shin splints

posterior tib tight + pulling on bone too
 ↓
 Shin splints inside shin pain
 ↓
 stress fracture
 ↓
 bone takes 80% of your weight
 ↓
 Strengthening the foot + surface
 ↓
 pain in shin

Impact injuries
 ↓
 jumpers → knee pain, patella tendon
 ↓
 triple jump heel injuries

triple jump → shoes w/ added cushioning in heel
 ↓
 knee + heel pain ← jumpers
 ↓
 Shin pain in all runners
 ↓
 heel cups in triple jump shoes
 ↓
 for practice
 ↓
 but don't always compete in berseas on heel, fat pads
 ↓
 pitch + irritate them
 ↓
 Foot strength + toe flexibility

Figure C2: Conversation notes with athletic trainer Meredith Cockerelle

Appendix D

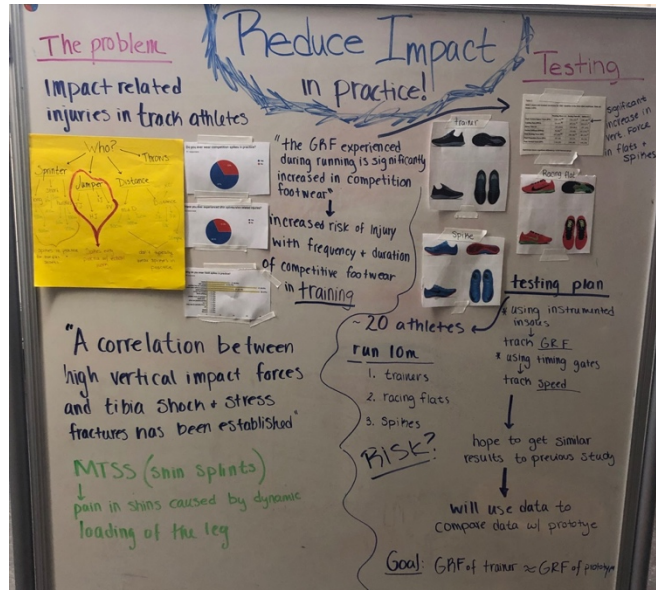


Figure E1: Brainstorming

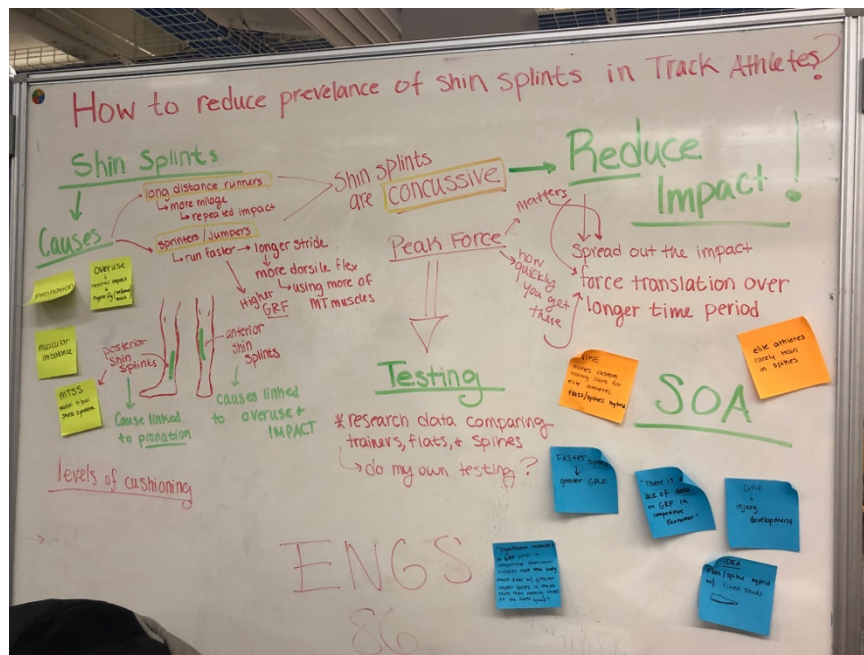


Figure E: Research

Appendix E

Track Spikes

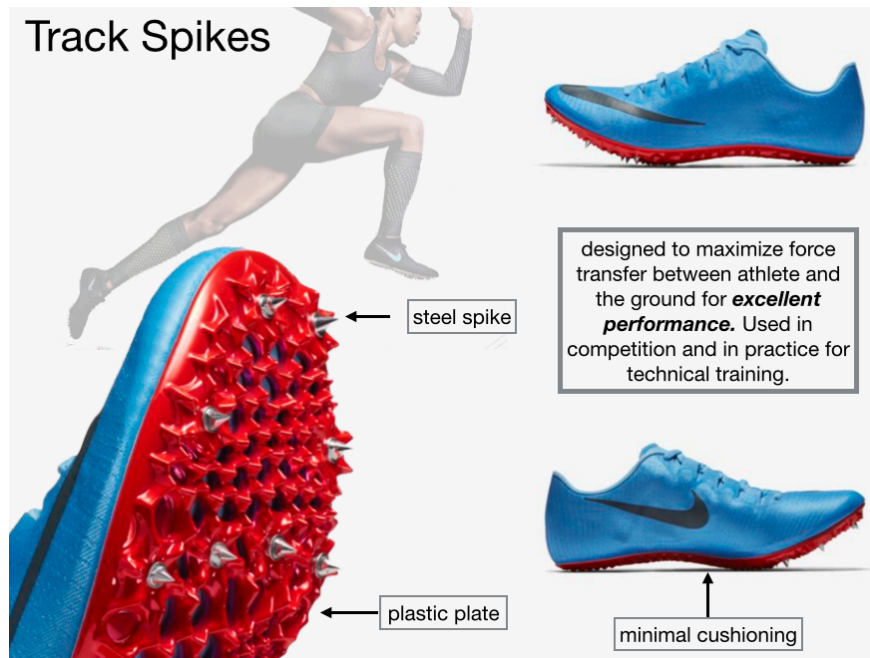


Figure F1: Track Spikes

Trainers



Figure F2: Trainers



Figure F1: Racing Flats

Appendix F



Figure G1: Spike bumpers mockup



Figure G2: Cramp-on cushioning mockup



Figure G3: Cramp-on spike mockup

		Durable	Easy on/off	Effective	Comfort	Consistent Stride	Safe	Feasibility	Weight	Total
	Scaling	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	(0-5)	
	Weighting (1-5)	3	4	5	5	4	4	2	3	
1	Spike Bumpers	3	1	4	5	5	4	3	5	115
2	Cramp on cushioning	1	2	4	1	1	1	2	3	57
3	Cramp on spikes	2	3	4	3	3	1	2	2	79
4	Flats/spikes hybrid	5	5	5	5	5	5	5	4	147

Figure G4: Alternatives Matrix

Number	Name	Description
1	Spike Bumpers	Added element to competition spikes. connected by way of spike screw
2	Cramp on cushioning	Added element to competition spikes. A second identical spike plate connected by longer spikes with a layer of cushioning in the middle.
3	Cramp on spikes	Added traction element to racing flats. Connected in a style similar to cramp on hiking spikes
4	Flats/spikes hybrid	Hybrid training shoe. A racing flat with a spike plate connected to the forefoot

Figure G5: Alternatives

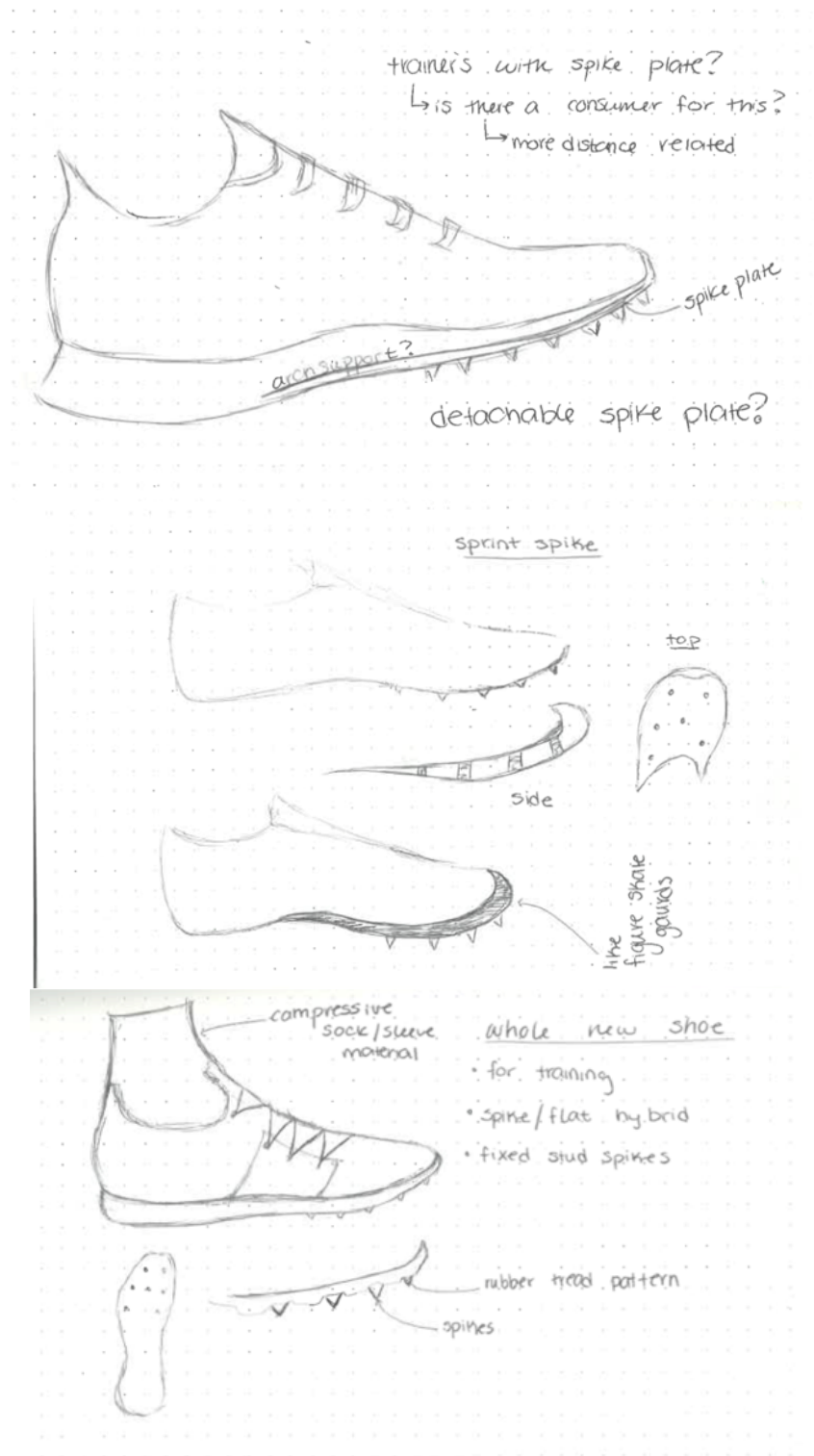


Figure G6: Initial sketches

Appendix G



Figure H1: Bumper Prototype

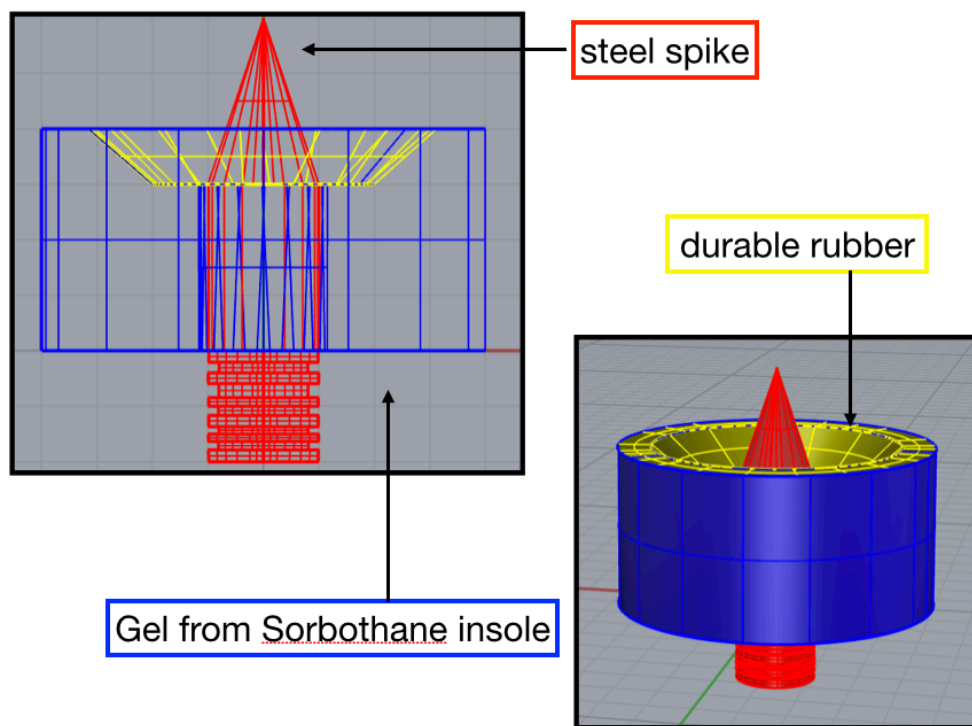


Figure H2: Bumper Rhino 3D model



Figure H3: Hybrid shoe Prototype



Figure H4: Building the shoe



Figure H5: Building the NB prototype

Appendix H



Figure I1: Hybrid shoe



Figure I2: Anatomy of Hybrid Shoe



Figure H6: Building the final product



Figure H7: Building the final product

Appendix I

Name		R	J	K	T
Trainers	Max L	1980	1880	1620	1630
	Max R	1900	2030	1560	1500
	avg.	1940	1955	1590	1565
Spikes	Max L	2140	1960	2070	1780
	Max R	2170	2080	2110	1670
	avg.	2155	2020	2090	1725
Proto	Max L	2050	1730	1520	1620
	Max R	2110	1870	1430	1460
	avg.	2080	1800	1475	1540

Figure J1: Testing Max GRF results

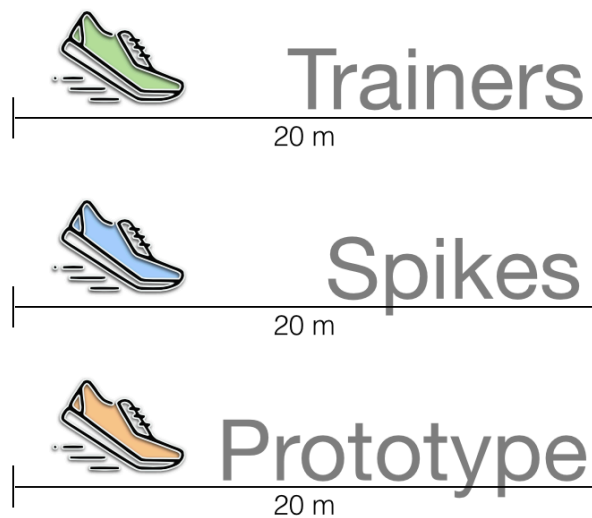


Figure J2:: Testing schematic

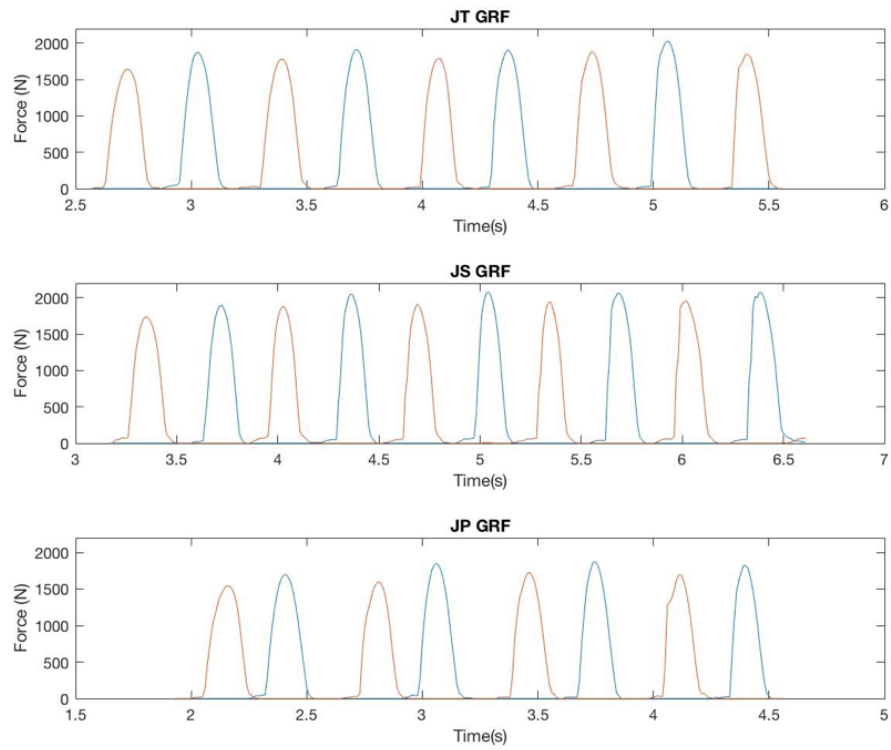


Figure J3: GRF graphs from testing

	T	R	J	K
Trainer	0.24 s	0.23 s	0.25 s	0.28 s
	0.61 s	0.65 s	0.63 s	0.66 s
Spike	0.28s	0.21 s	0.29 s	0.31 s
	0.63 s	0.65 s	0.61 s	0.67 s
Proto	0.24 s	0.23 s	0.27 s	0.28 s
	0.65 s	0.65 s	0.61 s	0.66 s

Figure J4: Stride length comparison

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